Answer all the following questions:

Question No. 1

1. Discuss the advantages and disadvantages of using robots in industry.
2. Briefly discuss the various robot components.
3. Explain the applications of robots with the features available at present and the future trend.
4. Discuss the impact of robotic induction on direct labour.

Question No. 2

1. The co-ordinates of a point Pabc in the mobile frame OABC is given by $[2,3,4]T$. If the frame OABC is rotated 30° with respect to OZ of the OXYZ frame, find the co-ordinates of Pxyz with respect to the base frame.

2. A mobile body reference frame OABC is rotated 45° about OX-axis of the fixed base reference frame OXYZ. If $Pxyz =[3,1,-2]T$ and $Qxyz =[-1,2,2] T$ are the co-ordinates with respect to OXYZ plane, what are the corresponding co-ordinates of P and Q with respect to OABC frame?

3. Determine the homogenous transformation matrix to represent a rotation of 30° about OY-axis and a translation of 10 units along OB-axis of the mobile frame.

4. Determine the homogenous transformation matrix to represent the following sequence of operations:
    - i. Rotation of 45° about OZ-axis.
    - ii. Translation of 10 units along OX-axis.
    - iii. Translation of -8 units along OB-axis.
    - iv. Rotation of 30° about OA-axis.

5. Determine the homogeneous transformation matrix to represent a rotation of 30o about OY-axis and a translation of 10 units along the OB-axis of the mobile frame.

6. Write down the homogenous transformation matrices for the co-ordinate frames situated at the points A, B, and C with respect to $OX_0Y_0Z_0$ frame in the figure shown. Write down by inspection and matrix operation the position and orientation of frame B with respect to frame C.
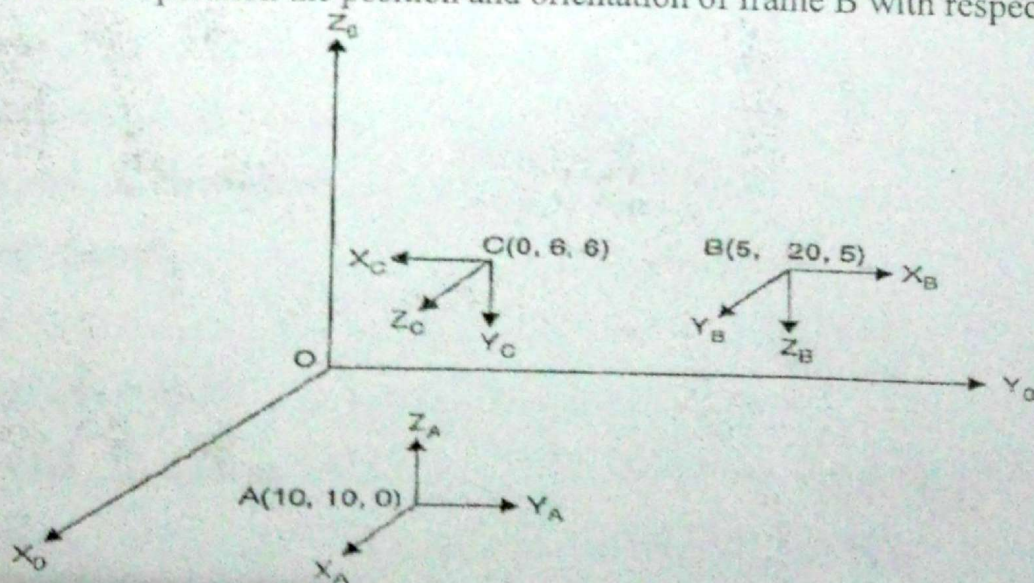
Problem 6. of Question No.2

* Computers and Automatic Control Department
* Course Title : Elective 4 (Robotics)   * Course Code : CCE 4242
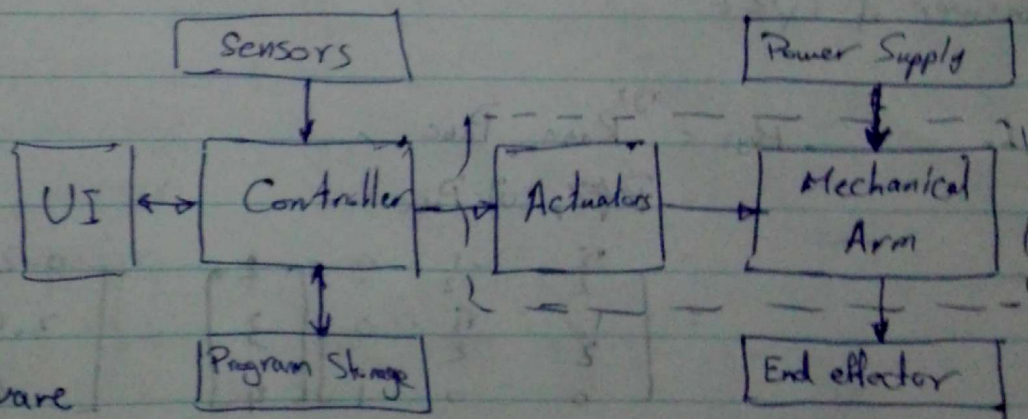
Midterm Exam Answer

Answer of Q1 :

1. Advantages   Disadvantages
   - Environmental Safety   - High Investement cost
   - Productivity   - Decision Intelligence
   - Unit low Cost   - Replacement of labour
   - Accuracy   - Degeneration of human skills
   - Repeatability
   - Can work with multiple stimulii
   - Advaced technological accessories

2- Robot Components
   - Arms
   - End effectors
   - Actuators
   - Sensors
   - Controllers
   - Software & Hardware
   - Power Supply

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       ┌─────────┐                              ┌─────────────┐
       │ Sensors │                              │ Power Supply│
       └────┬────┘                              └──────┬──────┘
            ↓                                          ↓
┌────┐  ┌──────────┐    ┌──────────┐           ┌─────────────┐
│ UI │↔ │Controller│ →  │ Actuators│    →      │ Mechanical  │
└────┘  └────┬─────┘    └──────────┘           │    Arm      │
            ↕                                   └──────┬──────┘
       ┌────────────┐                                  ↓
       │Program Strge│                          ┌─────────────┐
       └────────────┘                           │ End effector│
                                                └─────────────┘
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- *Applications of robots
  - Material handling   - Machine loading and uploading
  - Welding   - Spray Painting
  - Assembly Robots   - Surgical Manipulators

* Features available
  - Multiple nodes with one Controller
  - Multiple adaptable robot arm
  - Higher Payloads (by Servo tuning)
  - Use of micro controller & Embedded Systems
  - Network between Controllers and hardware
  - Use of Camera (Machine Vision)

4- Impact of robotic Induction on direct labour.
  - labour replaced by robot
  - Unemployment for most labours
  - Require labours with skills to deal with robot
  - Reduce practical skills of labours
  - Requires support and training Centers to teach new technologies

Answer of Q2:

1-
$$P_{xyz} = \overset{xyz}{R_{abc}} \; P_{abc}$$

$$= R(EZ, 30°) \; P_{abc}$$

$$= \begin{bmatrix} \frac{\sqrt{3}}{2} & -\frac{1}{2} & 0 \\ \frac{1}{2} & \frac{\sqrt{3}}{2} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ 3 \\ 4 \end{bmatrix} = \begin{bmatrix} 0.2321 \\ 3.598 \\ 4 \end{bmatrix}$$

2-
$$P_{abc} = \overset{-1}{R(x, 45)} \; P_{xyz}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} \\ 0 & -1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} 3 \\ 1 \\ -2 \end{bmatrix} = \begin{bmatrix} 3 \\ -1/\sqrt{2} \\ -3/\sqrt{2} \end{bmatrix}$$

5

$Q_{rob} = R^{-1}(x, 45) \, Q_{xyz}$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1/\sqrt{2} & 1/\sqrt{2} \\ 0 & -1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} -1 \\ 2 \\ 2 \end{bmatrix} = \begin{bmatrix} -1 \\ 2\sqrt{2} \\ 0 \end{bmatrix}$$

3. $H = H_r(Y, 30°) \, H_t(Y, 10)$

$$= \begin{bmatrix} \frac{\sqrt{3}}{2} & 0 & \frac{1}{2} & 0 \\ 0 & 1 & 0 & 0 \\ -\frac{1}{2} & 0 & \frac{\sqrt{3}}{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 10 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} \frac{\sqrt{3}}{2} & 0 & \frac{1}{2} & 0 \\ 0 & 1 & 0 & 10 \\ -\frac{1}{2} & 0 & \frac{\sqrt{3}}{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

4. $H = H_t(X, 10) \quad H_r(Z, 45°) \quad I \quad H_t(Y, -8) \quad H_r(X, 30°)$

$$= \begin{bmatrix} 1 & 0 & 0 & 10 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 6 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -8 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{1}{2} & 0 \\ 0 & \frac{1}{2} & \frac{\sqrt{3}}{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.7071 & -0.6124 & 0.3536 & 15.6569 \\ 0.7071 & 0.6124 & -0.3536 & -5.6569 \\ 0 & 0.5 & 0.8660 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

5. $°H_A :$ 1) translation about OX-axis   2) translation about OY.axis

$$°H_A = \begin{bmatrix} 1 & 0 & 0 & 10 \\ 0 & 1 & 0 & 10 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$^{o}H_{B} = $ 1) translation of $(5, 20, 5)$ w.r.t fixed frame
2) Rotation about OC-axis by $-90°$
3) Rotation about OB-axis by $180°$

$$^{o}H_{B} = \begin{bmatrix} 1 & 0 & 0 & 5 \\ 0 & 1 & 0 & 20 \\ 0 & 0 & 1 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 5 \\ 1 & 0 & 0 & 20 \\ 0 & 0 & -1 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$^{o}H_{c} = $ 1) translation of $(0, 6, 6)$ w.r.t fixed frame
2) Rotation about OB-axis by $+90°$
3) Rotation about OC-axis by $-90°$

$$^{o}H_{c} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 6 \\ 0 & 0 & 1 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ -1 & 0 & 0 & 6 \\ 0 & -1 & 0 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$^{c}H_{B} = \, ^{c}H_{o} \, ^{o}H_{B}$
$\quad = [^{o}H]^{-1} \, ^{o}H_{B}$

$$= \begin{bmatrix} 0 & -1 & 0 & 6 \\ 0 & 0 & -1 & 6 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 & 5 \\ 1 & 0 & 0 & 20 \\ 0 & 0 & -1 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} -1 & 0 & 0 & -14 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$